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Study of Breakdown Voltage of Liquid Dielectrics in Transformer Using Quickfield Software

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ABSTRACT

Transformer is vital equipment in power system. Liquid insulation are most commonly used in high voltage systems such as power transformer where it provides electrical insulation, extinguishes arcing and acts as a coolant agent to prevent the transformer from overheating. Thus, maintaining its dielectric strength at high level is the highest of the manufacturer. Measurements were made to assess the breakdown voltage in liquid dielectric with different electrode combinations like sphere-sphere, plane-plane, point-plane electrodes etc, and the result is obtained for three different oils: sunflower oil, coconut oil. The insulating properties are also affected by the distribution of electric field. Nitrogen bubbling is used to remove dissolved oxygen content in coconut oil. While to get the modelling of electrodes and simulation for electric field between the two electrodes, which is done by using quickfield software. The breakdown is proportional to electric stress on liquid dielectrics and this is verified by changing the gap length between the two electrodes. The paper presents implementation and the simulation of the above proposed theory.

Keywords: Breakdown voltage, Quickfield software, Liquid dielectrics

INTRODUCTION

In recent time, the demand for power growing many folds electrical utilities such as power transformers have shown to play an important role in powering many houses and cities and as consequence it is important to ensure its reliability for a safe and satisfactory operation of the power system. In recent time, the demand for power growing many folds electrical utilities such as power transformers have shown to play an important role in powering many houses and cities and as consequence it is important to ensure its reliability for a safe and satisfactory operation of the power system. During operation power transformer breakdown and produce certain gases. There gases are dissolved in insulating oil due to Electrical stress, Mechanical stress, and Thermal stress. For the purpose of transmission and distribution, transformers are important .The normal life expectancy of transformer is usually 25-30 years. The study is about analysing the performance of oil insulation from the dielectric withstand point of view and to predict the breakdown behaviour of transformer when failed with mineral oil or vegetable oil. They are affected when loaded beyond the name plate rating. They are affected by

- Lightning and switching surges that requires insulation
- Heat dissipate during the working of transformer due to the flow of eddy current

In order to overcome these Hazards liquid dielectric are used, i.e. oil immersed transformer are used. Since liquid dielectrics are used for insulation and cooling purpose.

PROBLEM STATEMENT

Mineral oil remains today, the most dielectric liquid dielectrics liquid in power transformer because of lower cost and physiochemical properties. However its impact on the Environment and particular on aquatic resources and soil is the main problem, goal is predict the dielectric performance of two oils under electrode configuration.

ABOUT SOFTWARE

- Quick Field is a user friendly and powerful Finite Element Analysis package for electromagnetic, thermal, and stress analysis simulations. Quick Field can be used without knowing the mathematical algorithms and details of their implementation.
- Standard analysis types include:
- Electrostatics and transient electric analysis.
- DC and AC conduction analysis.
- Linear and nonlinear DC and transient magnetic. AC magnetic (involving eddy current analysis).
- Linear and nonlinear, steady state and transient heat transfer and diffusion.
- Linear stress analysis
- Coupled problems.

QuickField is a PC-oriented interactive environment for electromagnetic, thermal and stress analysis. Here, Electrostatic Analysis is used to design and analyze different cases. The available options for electrostatic analysis: Material properties. Loading sources. Boundary conditions. Post recessing results. Special features and 3D analysis limitations.

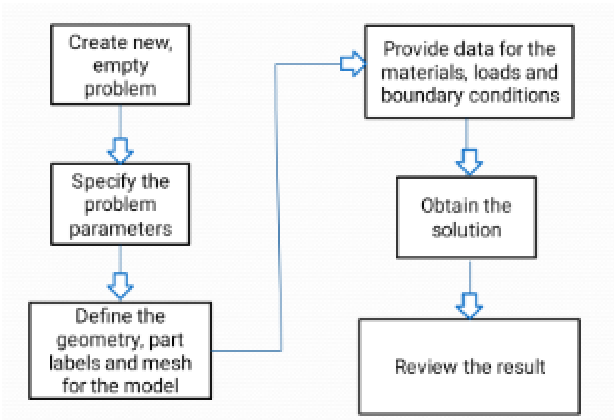


Fig1: Sequence of phases in Quickfield Software

RESULT AND DISCUSSION

In this study, we have considered three different electrode configurations: sphere-sphere, plane-plane and point-plane; each of which is analyzed for three different oils used: Mineral oil, sunflower oil and coconut oil. The test cell for conducting the experiment is constricted as per the measurement Standards-IS 6792/1972. The result is also verified by varying the gap length between the two electrodes.

The simulated output from the software is shown in the form of electric field distribution in the modelled setup, field picture properties and the graph showing variation in the parameters.

Simulated Output:- CASE 1-

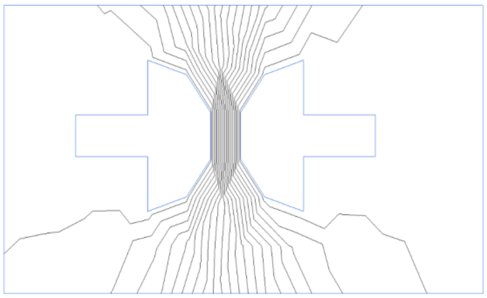


Fig1a:Simulated output for electric field distribution for sphere-sphere configuration

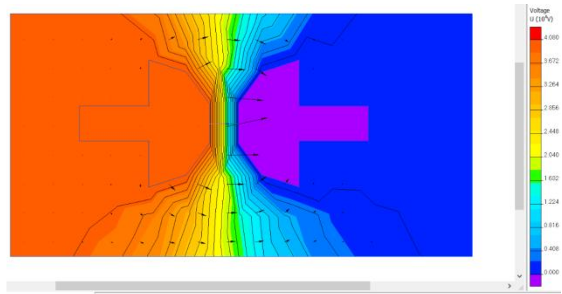


Fig 1b: Field picture property showing voltage levels for sphere-sphere configuration

Due to sphere-sphere configuration of electrodes, the gap distance between the electrodes is not equal, and thus the electric field is distributed widely throughout the dielectric. [Fig 1a]

The voltage variation in the test cell can be observed here. Voltage is given to the HV electrode, and the voltage decreases as the distance increases from HV electrode to ground electrode due to the spherical geometry of the electrodes. [Fig 1b)

CASE 2:

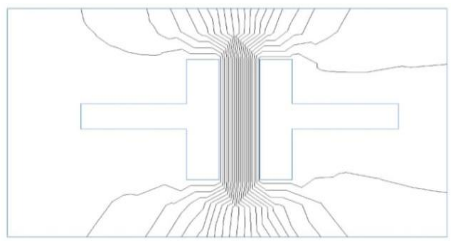


Fig 2a: simulated output for electric field distribution for plane-plane configuration

Due to plane-plane configuration of the electrodes, the gap distance between electrodes remains constant, and the electric field is not distributed widely as in sphere-sphere configuration, and is concentrated in the gap length. Thus, breakdown voltage is much lower compared to sphere-sphere configuration of the electrodes. [Fig 2a]

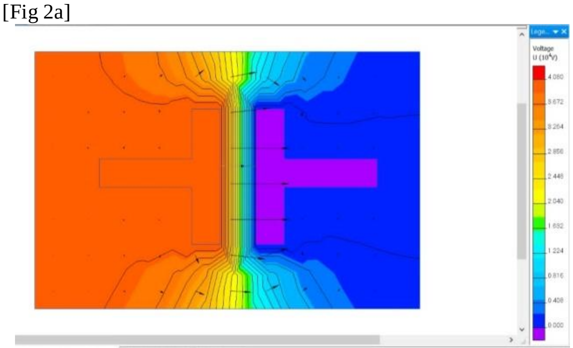
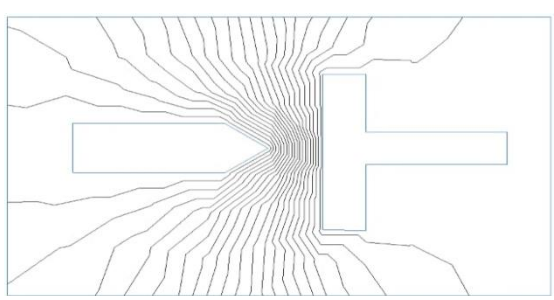


Fig 2b: Field picture property showing voltage levels for plane-plane configuration

Due to plane-plane configuration of the electrodes, the gap distance between electrodes remains constant, and the electric field is not distributed widely as in sphere-sphere configuration, and is concentrated in the gap length. Thus, breakdown voltage is much lower compared to sphere-sphere configuration of the electrodes. [Fig 2a]



CASE 3: Fig3a:Simulated output for electric field distribution for point-plane configuration

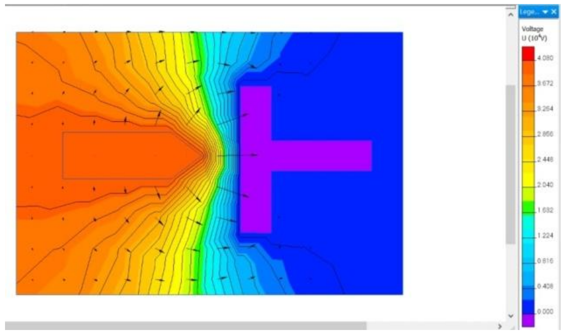


Fig 3b: Field picture property showing voltage levels for point-plane configuration

Due to the point-plane electrode configuration the gap distance between the electrodes is non-uniform, and the field is much stressed near the pointed surface of the HV electrode. Here, the breakdown voltage is the least when compared to the other two configurations. [Fig 3a]

The field distribution is non-uniform in the point-plane configuration. This causes the breakdown of the dielectric at a lower BDV than in the other two cases. [Fig 3b]

Plots -

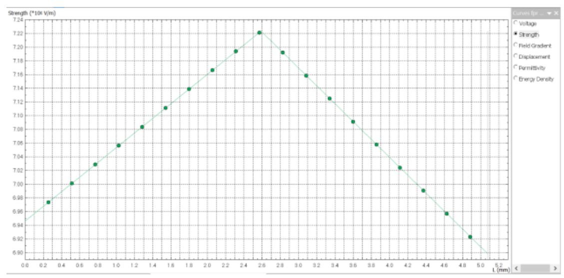


Fig 1c: Graph showing variation of electric strength in gap length of sphere-sphere configuration

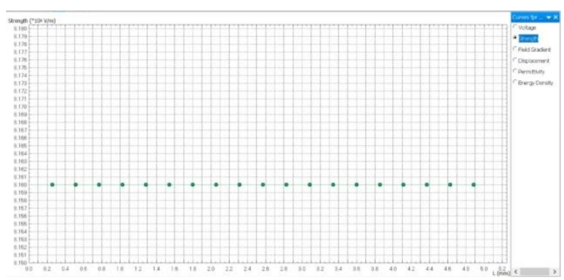


Fig 2c: Graph showing variation of electric strength in gap length of plane-plane configuration

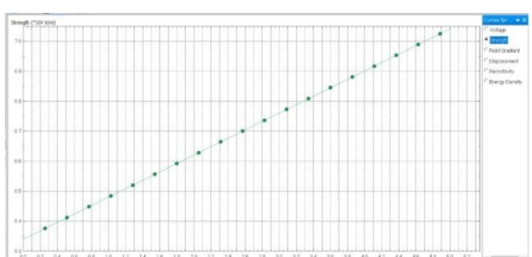


Fig 3c: Graph showing variation of electric strength in gap length of point-plane configuration

From the above graphs, we infer that, the electric strength between sphere-sphere electrodes initially increases, reaches a maximum and then decreases. The electric strength on the surface of the electrode will be minimum and as the distance increases from HV electrode, the strength goes on increasing. Then, due to the spherical geometry of the electrodes, the field starts distributing widely and hence the electric strength decreases as it proceeds towards the ground electrode.[Fig 1c]

But in plane-plane configuration, the electric strength between the two electrodes remains constant. This is because; the electric field distribution between the electrodes is uniform, which makes the electric strength to be constant as it progresses from HV electrodes to ground electrode. [Fig 2c]

In point-plane electrode configuration, the electric strength goes on increasing from HV electrode to ground electrode. Due to the pointed surface, field is concentrated initially and then starts distributing, resulting in uniform increase in the strength. [Fig 3c]

But if we increase the gap distance here, the electric strength starts decreasing slowly as the field lines start distributing more widely into the dielectric.

Also, we can observe that the effect of the shape of the electrode on the BDV is not stronger as that due to the effect of gap length.

The above simulated outputs show the results for Mineral Oil used as a dielectric. The same three cases are repeated by taking Sunflower Oil and Coconut Oil as the dielectric and also by varying the gap distances between the two electrodes.

At room temperature the permittivity values of Mineral Oil and Sunflower Oil are 2.3 and 3.02 respectively.

The variation in the electric field strength in case of Sunflower Oil and Coconut Oil is similar to that when Mineral Oil is used. But breakdown voltage occurs at a much higher value. This is due to the fact that the dielectric constant value of vegetable oil has greater value and dielectric loss factor of vegetable oil has lesser value than that of transformer oil at all frequencies and temperatures.

ADVANTAGES OF VEGETABLE OIL OVER MINERAL OIL

- We selected coconut oil and sunflower oil as a vegetable oils
- The coconut oil and sunflower oils are used as fluids increasingly replacing mineral oil based products in the market place. These oils are successful because they perform better than mineral oil product and they provide definite environmental and safety gasses.
- The main advantages of vegetable oil I.e. their biodegradability. They are generally renewable and less toxic; mineral oil is from non-renewable sources.
- The flashpoint of vegetable oil is higher compared to mineral oil. The flashpoint is specified for safety of a transformer operation at high temperature.
- Breakdown voltage of high viscosity index compared to mineral oil. Viscosity is a frequency used measurement for change of fluids viscosity with temperature.
- Vegetable oils have better dielectric insulation performance compared to mineral oil.

CONCLUSION

From the above case studies we can infer that the breakdown occurs at a point, when the electric strength at that point teaches a certain maximum value, thus making a part of the dielectric as a conducting medium. The three different combinations of electrodes exhibit three different field distributions when high voltage is applied, hence results in different breakdown voltages'.

The study shows that the breakdown voltage is much higher for sphere-sphere electrode configurations than the other two, which is necessary for the protection of the insulation systems also due to the above mentioned demerits of Mineral oil. Sunflower oil can be used as an alternative in transformers. As its breakdown value is much higher compared to that of the Mineral oil, thus proving to be a better liquid dielectric.

The simulated results are verified along with the previously obtained practical results. It shows the results similar to that when the experiment is practically conducted.

Further, from the above discussion of test results, we can conclude that-

- The breakdown voltage mainly depends on the configuration of the electrodes
- The geometry of the electrodes gives the variation in the breakdown voltages. However, the variation in gap distances also plays a vital role in the breakdown.
- The breakdown voltages of a given set of electrodes depend on the distribution of electric field lines between them.
- lf the flux lines are more uniformly distributed then high voltages are required for the breakdown. If the field lines are concentrated towards the electrode then the breakdown voltage is of low value.

FUTURE SCOPE

The goal is to obtain the highest dielectric strength possible, in order to prevent the transformer damage due to the defects in insulation system, by conducting case studies in every combination of electrodes and oils.

This study can be further extended to analyze the breakdown of the oil used as insulator, at temperatures other than the room temperature. Also the study can be done in case of presence of air bubbles in the gap distance, and different types of Oil Impregnated Paper **(OIP)** as an insulating barrier, placed between the two electrodes, immersed in the oil.

ACKNOWLEDMENT

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